



National Pollutant Inventory

Emission Estimation Technique Manual

for

**Concrete Batching
and Concrete Product
Manufacturing**

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**EMISSION ESTIMATION TECHNIQUES
FOR
CONCRETE BATCHING AND CONCRETE PRODUCT MANUFACTURING**

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CONCRETE BATCHING AND CONCRETE PRODUCT MANUFACTURING

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1.0 Introduction

The purpose of all Emission Estimation Technique (EET) Manuals in this series is to assist Australian manufacturing, industrial and service facilities to report emissions of listed substances to the National Pollutant Inventory (NPI). This Manual describes the procedures and recommended approaches for estimating emissions from facilities engaged in concrete batching and concrete product manufacturing.

The activities covered in this Manual apply to facilities primarily engaged in the following activities:

- Concrete Batching
- Concrete Product: Concrete boxes, posts, poles, railway sleepers, roof
 Manufacturing and floor tiles, sinks and tubs, troughs, tanks, pots,
 blocks, bricks, building boards, concrete/styrofoam
 composite products, autoclaved aerated products, and
 terrazzo products.

EET MANUAL: Concrete Batching and Concrete Product Manufacturing

HANDBOOK: Concrete Product Manufacturing

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This Manual was drafted by the NPI Unit of the Queensland Department of Environment and Heritage on behalf of the Commonwealth Government. It has been developed through a process of national consultation involving State and Territory environmental authorities and key industry stakeholders.

2.0 Processes and Emissions

The following section presents a brief description of the Concrete Batching and Concrete Product Manufacturing Industry and identifies likely sources of emissions.

2.1 Process Description

The concrete batching and concrete product manufacturing activities covered in this Manual includes facilities primarily engaged in the mixing of cement and aggregate into concrete, as well as concrete products, including aerated and concrete composite products.

The term concrete refers to a product formed by two principal components: aggregate and slurry. Aggregate, which can be either natural or man-made, consists of various grades of sand, gravel, crushed stone, or slag. The slurry is composed of cement, water, and sometimes, entrained air. The cement slurry makes up approximately 25 to 40 percent by volume of concrete.

Figure 1 shows the concrete batching processes and likely emission points. As each facility in Australia is likely to be unique, operators are strongly advised to develop a flow diagram for their own facility that details the input of materials and NPI-listed substances, as well as the waste sources and emissions resulting from the operation of each process:

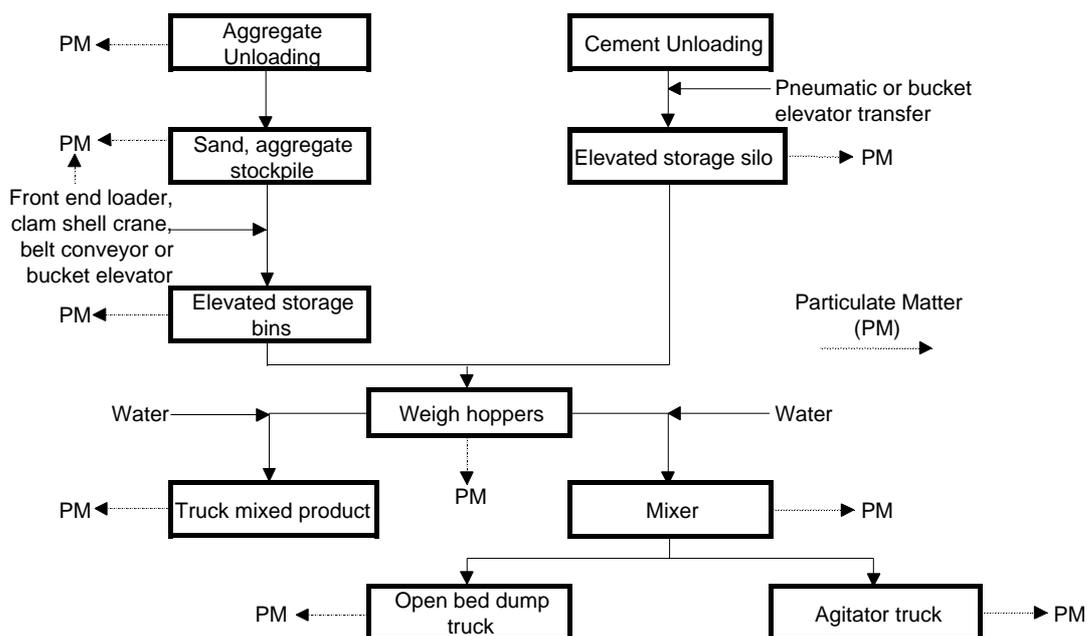


Figure 1. Basic Process Steps for Concrete Batching

(Source:USEPA AP-42, 1995)

Some concrete mixtures include hydrochloric acid, acetone, styrene, glycol ethers, or butyl benzyl phthalate as additives. Manufacturers utilise different combinations of pastes and aggregates to produce grades of concrete that vary in terms of cost, strength, durability, and rigidity.

The many types of products fashioned from concrete include bricks, architectural blocks, columns, paving materials, foundations, curbing, storage tanks, roofing-tiles, and pipes. Facilities covered in this Manual produce both ready-mixed concrete

which is unhardened concrete material, and a multitude of concrete products, such as those listed above. Table 1. indicates the wide variety of concrete products, and the range of production activities involved.

Table 1. The Range of Concrete Products Manufactured in Australia

Concrete Product	Concrete Product
Box culverts	Concrete mouldings
Concrete pipes (including pre-stressed)	Ornamental concrete or terrazzo product
Autoclaved aerated products	Prefabricated panels
Concrete blocks	Concrete posts and poles
Concrete bricks	Concrete railway sleepers
Building boards	Concrete roof tiles
Concrete cisterns	Concrete roof components
Monuments and grave markers	Concrete sinks and tubs
Floor and wall tiles	Concrete troughs and tanks
Flower pots	Terrazzo products
Meter boxes	Concrete tiles
Concrete/styrofoam composite products	Wall fittings and terrazzo

Source: Queensland Department of Environment and Heritage, 1998.

Concrete batching plants store, convey, measure, and discharge concrete constituents into concrete mixers for transport to the job site. The raw materials can be delivered to a batching plant by road or by rail, and are then transferred to elevated storage silos pneumatically, or by bucket elevator. The sand and coarse aggregate are transferred to elevated bins by front-end loader, clam-shell crane, belt conveyor, or bucket elevator. From the elevated bins, the constituents are fed by gravity, or screw conveyor, to weigh hoppers that combine the proper amounts of each material.

The constituents are then fed from the weigh hopper to agitator trucks, where the concrete is mixed on the way to the site where it is to be used. Central mix facilities mix the concrete on site and then transfer it either to an open bed dump truck or a concrete mixer for transport to the job site. Shrink mixed concrete is partially mixed at the central mix plant, then completely mixed in the concrete mixer on the way to the job site. Dry batching, where concrete is mixed and hauled to the construction site in dry form, is seldom used in Australia.

2.2 Emission Sources and Control Technologies

Concrete batching and product manufacturing generates emissions of particulate matter (PM₁₀). Product manufacturing may also generate emissions of paint wastes, and plant maintenance wastes - the latter two often contain listed NPI substances. Table 2 illustrates some of the raw materials used in production processes, and highlights the likely emission points.

Table 2. Concrete Product Manufacturing Process Material Inputs and Pollutant Outputs

Process	Material Input	Air Emissions *	Water or Land Emissions	Other Wastes & Emissions
Concrete Batching and Product Manufacturing	Cement, sand, lime-stone, gravel, aggregate material, acetone, glycol ethers, hydrochloric acid, styrene, solvents in paints and clean-up	Cement dust, sand and gravel dust, constituents from fuel burning, VOCs from paint and solvent application and cleaning	Wastewaters containing residual solvents, other VOCs, acids, and particulates	Equipment and repair emissions and wastes, paint sludges containing residue solvents

Adapted from: USEPA Sector Notebook Project, 1995.

*For more detail on Air Emissions, please refer to the EET Manual for Combustion in Boilers.

2.2.1 Emissions to Air

Air emissions may be categorised as :

Fugitive Emissions

These are emissions that are not released through a vent or stack. Examples of fugitive emissions include dust from stockpiles, volatilisation of vapour from vats, open vessels, spills, and materials handling. Emissions emanating from ridgeline roof-vents, louvres, and open doors of a building, as well as equipment leaks, and leaks from valves and flanges are also examples of fugitive emissions. Emission factor EETs are the usual method for determining losses through fugitive emissions.

Fugitive emissions from the concrete industry include particulate matter (PM₁₀) from vehicular movements, and the storage, unloading and conveying of aggregates, and other material inputs. (Emissions from concrete product manufacturing may also include various volatile organic compounds (eg., xylenes), from solvent and paint usage.)

Point Source Emissions

These emissions are exhausted into a vent or stack and emitted through a single point source into the atmosphere. Table 3 highlights the most commonly emitted substances from the United States Concrete Product Manufacturing Industry.

Table 3. NPI-Listed Substances Emitted to Air by the Concrete Products Industry.

Listed Substance	Listed Substance
Ammonia	Phenol
Formaldehyde	Styrene
Hydrochloric acid	Sulphuric acid
Hydrogen fluoride	Toluene
Methanol	Xylenes (mixed isomers)
Particulate matter (PM ₁₀)	

Adapted from: USEPA, *Sector Notebook Project*, 1995.

Air emission control technologies, such as water sprays and fabric filters are commonly installed to reduce the concentration of substances in venting air streams prior to emission. Where such emission abatement equipment has been installed, and where emission factors from uncontrolled sources have been used in an emission estimation, the collection efficiency of the abatement equipment needs to be considered. Guidance on applying collection efficiencies to emission factor equations is provided in later sections.

With regards to emission controls for PM₁₀, in the absence of measured data, or knowledge of the collection efficiency for a particular piece of equipment, an efficiency of 90% should be used in the emission factor equation to calculate actual mass emissions. This default should only be used if there is no other available control efficiency.

2.2.2 Emissions to Water

Manufacturers who apply finishes to concrete products generate various paint wastes. When solvent-based paints are used, the spray guns and application equipment must also be cleaned with solvent, thereby producing spent solvent waste. These wastewaters can also contain listed substances, such as ethanol, ethyl acetate, and other volatile organic compounds.

Emissions of substances to water can be categorised as discharges to:

- Surface waters (eg. lakes, rivers, dams, and estuaries)
- Coastal or marine waters
- Stormwater.

Because of the significant environmental hazards posed by emitting toxic substances to water, most facilities emitting NPI-listed substances to waterways are required by their relevant State or Territory environment agency to closely monitor and measure these emissions. This existing sampling data can be used to calculate annual emissions.

If no wastewater monitoring data exists, emissions to process water can be calculated based on a mass balance or using emission factors. The most appropriate method for determining emissions to the environment via wastewaters is to use direct measurement, however, you may use other EETs for the purpose of reporting to the NPI.

The discharge of listed substances to a sewer or tailings dam does not require you to report to the NPI (See also Section Three of *The NPI Guide*).

2.2.3 Emissions to Land

Emissions of substances to land on-site include solid wastes, slurries, sediments, spills and leaks, storage and distribution of liquids and may contain listed substances. These emission sources can be broadly categorised as :

- surface impoundments of liquids and slurries
- unintentional leaks and spills.

3.0 Emission Estimation Techniques

Estimates of emissions of NPI listed substances to air, water and land should be reported for each substance that triggers a threshold. The reporting list and detailed information on thresholds are contained in *The NPI Guide* at the front of this Handbook.

There are four types of emission estimation techniques (EETs) that may be used to estimate emissions from your facility.

The four types described in *The NPI Guide* and in this Manual are:-

- sampling or direct measurement
- mass balance
- fuel analysis or other engineering calculations
- emission factors

Select the EET (or mix of EETs) that is most appropriate for your purposes. For example, you might choose to use a mass balance to best estimate fugitive losses from pumps and vents, direct measurement for stack and pipe emissions, and emission factors when estimating losses from storage tanks and stockpiles.

If you estimate your emission by using any of the EETs described in *The NPI Guide* and in this Manual, your data will be displayed on the NPI database as being of 'acceptable reliability'. Similarly, if your relevant environmental authority has approved the use of emission estimation techniques that are not outlined in *The NPI Guide* and in this Manual, your data will also be displayed as being of 'acceptable reliability'.

This Manual seeks to provide the most effective emission estimation techniques for the NPI substances relevant to this industry. However, the absence of an EET for a substance in this Manual does not necessarily imply that an emission should not be reported to the NPI. The obligation to report on all relevant emissions remains if reporting thresholds have been exceeded.

You are able to use emission estimation techniques that are not outlined in this document. You must, however, seek the consent of your relevant environmental authority. For example, if your company has developed site specific emission factors, you may use these if approved by your relevant environmental authority.

You should note that the EETs presented in this Manual relate principally to average process emissions. Emissions resulting from non-routine events are rarely discussed in the literature, and there is a general lack of EETs for such events. However, it is important to recognise that emissions resulting from significant operating excursions and/or accidental situations (eg: spills) will also need to be estimated. Emissions to land, air and water from spills must be estimated and added to process emissions when calculating total emissions for reporting purposes. The emission resulting from a spill is the net emission, ie., the quantity of the NPI reportable substance spilled, less the quantity recovered or consumed during clean up operations.

3.1 Direct Measurement

You may wish to undertake direct measurement in order to report to the NPI, particularly if you already do so in order to meet other regulatory requirements.

However, the NPI does not require you to undertake additional sampling and measurement. For sampling data to be adequate and able to be used for NPI reporting purposes, it would need to be collected over a period of time and be representative of operations for the whole year.

3.1.1 Sampling Data

Stack sampling test reports often provide emissions data in terms of kg per hour or grams per cubic meter (dry standard). Annual emissions for NPI reporting can be calculated from this data. Stack tests for NPI reporting should be performed under representative (ie. normal) operating conditions. You should be aware that some tests undertaken for a State or Territory license condition may require the test be taken under maximum emissions rating, where emissions are likely to be higher than when operating under normal operating conditions.

Table 4. List of Variables and Symbols

Variable	Symbol	Units
Concentration	C	parts per million volume dry
Molecular weight	MW	kg/kg-mole
Molar volume @ STP	V	22.4 m ³ /kg-mole @ 0°C and 101.3 kPa
Flow rate	Q _a	actual cubic metres per second (m ³ /s)
Flow rate	Q _d	cubic metres per second (m ³ /s)
Emissions	E _i	typically kg per hour of pollutant i
Annual emissions	E _{kpy,i}	kg per year of pollutant i
Filter catch	C _f	grams (g)
PM ₁₀ concentration	C _{PM}	g/m ³
Metered volume at standard temperature and pressure	V _{m, STP}	cubic metres (m ³)
Temperature	T	°C
Activity rate	A	tonnes per year (t/yr)
Annual operating hours	OpHrs	hours per year (hr/yr)
Specific gravity of coating	SG	kilograms per litre (kg/L)
Evaporation rate	Evap	percentage (%)
Control efficiency	CE	percentage (%)
Annual volume of coating	A	litres per year (L/yr)
Content of VOC species	S	percentage (%)

Source: Queensland Department of Environment and Heritage, 1998.

Estimating Emissions to Air

Because vent or stack testing is relatively uncommon for Australian concrete product manufacturers, emissions test data for these facilities are typically in the form of worker exposure monitoring results conducted for compliance with Worksafe Australia exposure standards. This gas concentration data may be used in conjunction with exhaust system flow rates to calculate fugitive emissions from a room, floor, or building. Equation (1) calculates these emissions.

$$E_{kpy,i} = (Q * 3\ 600 * OpHrs * C_i * 0.0858 * M_i) / 1 * 10^6 \quad (1)$$

where:

E _{kpy,i}	=	emissions of VOC or PM ₁₀ species i, kg/yr
Q	=	flow rate through exhaust ventilation system, m ³ /s
3 600	=	conversion factor, s/hr
OpHrs	=	exhaust system operating hours, hr/yr
C _i	=	concentration of VOC or PM ₁₀ species i, ppm _v
0.0858	=	molar volume of gas at 20 °C, mole/m ³
M _i	=	molecular weight of VOC or PM ₁₀ species i, kg/kg-mole
1*10 ⁶	=	1*10 ⁶ , million m ³

The following example illustrates the application of Equation (1).

Example 1. - Using Sampling Data

This example shows how Equation (1) is used to calculate fugitive emissions of xylenes from a building where concrete roof-tiles are being coated. The following data is given:

- the building exhaust flow rate (FR) is 10.1 m³/s
- the exhaust system operates for 7 920 hr/yr, OpHrs
- occupational hygiene data indicates that the concentration of mixed isomer xylenes in the building (C_{it}) is 0.1 ppm_v
- the molecular weight of mixed xylenes (M_i) is 106 kg/kg-mole

Xylenes emissions are calculated as follows:

$$\begin{aligned} E_{kpy,i} &= (FR * 3\,600 * OpHrs * C_{it} * 0.0858 * M_i) / 1 * 10^6 \\ &= (10.1 * 3\,600 * 7\,920 * 0.1 * 0.0858 * 106) / 1 * 10^6 \\ &= 262 \text{ kg xylenes/yr} \end{aligned}$$

Estimating Emissions to Water

Because of the significant environmental hazards posed by emitting toxic substances to water, most facilities emitting listed NPI substances to waterways are required by their relevant State or Territory environment agency to closely monitor and measure these emissions. This existing monitoring data on pollutant concentrations in water can be used to calculate annual emissions by the use of Equation (2).

$$E_{kpy,i} = C_i * V * OpHrs / 1\,000\,000 \quad (2)$$

where:

$$\begin{aligned} E_{kpy,i} &= \text{emissions of pollutant i, kg/yr} \\ C_i &= \text{concentration of pollutant i in wastewater, mg/L} \\ V &= \text{hourly volume of wastewater, L/hr} \\ OpHrs &= \text{operating hours per year for which data apply, hr/yr} \\ 1\,000\,000 &= \text{conversion factor, mg/kg} \end{aligned}$$

In applying Equation (2) to water emission calculations, monitoring data should be averaged and only representative concentrations used in emission calculations. The total emissions of a listed substance should equal the amount used during the year, minus the amount incorporated into products, minus the amounts destroyed in on-site treatment or transferred off-site for disposal by another facility. In estimating emissions of metals, it is particularly helpful to first estimate the amount incorporated into products before proceeding to individual emission estimates, as this will provide a reference point.

3.1.2 Continuous Emission Monitoring System (CEMS) Data

A continuous emission monitoring system provides a continuous record of emissions over time, usually by reporting pollutant concentration.

Once the pollutant concentration is known, emission rates are obtained by multiplying the pollutant concentration by the volumetric gas, or liquid flow rate of that pollutant.

It is important to note that prior to using CEMS to estimate emissions, you should develop a protocol for collecting and averaging the data in order that the estimate satisfies your relevant environmental authority's requirement for NPI emissions estimations.

3.2 Mass Balance

A mass balance identifies the quantity of substance going in and out of an entire facility, process, or piece of equipment. Emissions can be calculated as the difference between input and output of each listed substance. Accumulation or depletion of the substance within the equipment should be accounted for in your calculation.

Estimating emissions of listed substances from concrete product manufacturing activities can be undertaken across a process or entire facility using a mass balance. Using industry-wide emission factors will not necessarily provide an accurate reflection of the actual emissions from any facility because of the wide range of possible operational practices within the industry.

The operational activities that are process or facility specific, and need to be factored into a mass balance equation, include:

- the range and mix of process activities and product manufacturing that occur at any facility;
- the amount of paint, solvents, and acid solutions used at the facility;
- the volatile organic compound (VOC) content, volatility and weight percentage of listed substances in the paints and solvent cleaning solutions used;
- the amount of material that is recovered and recycled, but not reused within the facility; and
- the control equipment used, and the control efficiency of this equipment.

The mass balance approach requires the addition of all materials containing NPI pollutants received at the facility and then the subtraction of all the known losses or transfers of the material off-site, including finished product and waste materials. The difference is assumed to have been emitted to air, water, or land. The quantity received, and the quantity lost or used should be for the same time period, typically 1 July to 30 June (the NPI reporting year).

Equation (3) can be used for calculating emissions using the mass balance approach.

$$E_{kpy,i} = Q_r - Q_p - Q_{rec} - Q_w - Q_i \quad (3)$$

where:

$$E_{kpy,i} = \text{emissions of VOC or PM}_{10} \text{ species } i, \text{ kg/yr}$$

Q_r	=	quantity of VOC or PM ₁₀ species i that is received as raw material, kg/yr
Q_p	=	quantity of VOC or PM ₁₀ species i that is contained in the final product or article, kg/yr
Q_{rec}	=	quantity of VOC or PM ₁₀ species i that is recovered on-site by all methods (such as solvent recovery), kg/yr
Q_w	=	quantity of VOC or PM ₁₀ species i that is contained in all wastes (such as wastewater, sludge, drum residue) generated during the NPI reporting year, kg/yr
Q_i	=	quantity of VOC or PM ₁₀ species i that remains on-site in the raw material inventory or stock pile, kg/yr

The following example shows the application of Equation (3).

Example 2. - Using a Mass Balance

This example shows how total xylene emissions for a concrete roof-tile manufacturing facility can be calculated using Equation (3). Given data is as follows:

- In a given year, a concrete tile facility receives 70 000 kg of xylenes (Q_r) contained in 140 000 litres of concrete roof-tile paint.
- Based on the total amount of product shipped off-site, and records of product composition, the facility estimates that the amount of xylenes shipped off-site contained in roof tile coatings is 21 000 kg.
- The amount of xylenes that were recovered by the facility's distillation system (Q_{rec}) is 20 000kg.
- Based on waste composition analyses, the amount of waste transferred off-site, and wastewater discharge rates, the facility estimates that the amount of xylenes found in all wastes generated during the year (Q_w) is 5 000kg.
- The amount of xylenes contained in the facility's paint inventory at the end of the reporting year (Q_i) is 15 000kg.

Emissions of xylenes are calculated as follows:

$$\begin{aligned} E_{kpy,i} &= Q_r - Q_p - Q_{rec} - Q_w - Q_i \\ &= 70\,000 - 21\,000 - 20\,000 - 5\,000 - 15\,000 \\ &= 9\,000 \text{ kg xylenes/yr} \end{aligned}$$

3.3 Engineering Calculations

An engineering calculation is an estimation method based on physical/chemical properties (eg. vapour pressure) of the substance, and mathematical relationships (eg. ideal gas law).

Estimating VOC Emissions

The methodology for calculating volatile organic compound (VOC) emissions from coating or sealer application to concrete product or concrete mixing operations is quite straightforward. For each type of coating, sealer, or paint fluid used, the quantity of total product used is multiplied by the VOC content and evaporation rate of the coating, sealer, or paint to obtain the total VOC emissions from the use of that product.

If any type of air pollution control equipment is in use, then the VOC emissions estimate is reduced by the effectiveness of the equipment to reflect the effects of the control device. To report individual listed VOCs, (eg., toluene or xylenes), the same method is applied, only the quantity of coating used is multiplied by the individual content of the VOC being measured. The methodology is expressed by Equation (5).

$$E_{\text{VOC}} = \sum_i [(A_i * SG_i) * (S_{\text{VOC},i}/100) * \text{Evap} * (1 - (\text{CE}/100))] \quad (4)$$

where:

- E_{VOC} = total emissions of VOCs from concrete product operations, kg/yr
- A_i = total volume of coating, sealer, or paint type i used in the reporting year, L/yr
- SG_i = specific gravity of the coating, sealer, or paint type i, kg/L
- $S_{\text{VOC},i}$ = content of individually listed VOC substance for coating, sealer, or paint type i, %
- Evap = evaporation rate of VOC for coating, sealer, or paint type i, fraction
- CE = control efficiency factor, %
- i = coating type, paint, release-agent, concrete-sealer, thinner, primer

The quantities of each type of coating used are usually available in litres. Material and Safety Data Sheets (MSDS), or paint and coating manufacturers and suppliers, should be consulted to obtain the VOC content, VOC speciation profile, and the evaporation rate. Some default VOC content values are provided in Table 5.

Table 5. VOC Content of Common Surface Coatings

Surface Coating	VOC Content (kilograms/litre)
Paint (solvent based)	0.672
Paint (water based)	0.156
Enamel	0.420
Concrete-Sealer	0.732
Primer	0.792
Varnish and Shellac	0.396
Thinner	0.883
Adhesive	0.528

Source: Queensland Department of Environment and Heritage, 1998.

The following example illustrates the use of Equation 4:

Example 3. - Calculating VOC Emissions

50 000 litres of a concrete coating/sealer is used in a roofing tile manufacturing facility over a reporting year. A solvent recycling system operates at an efficiency of 60 % for the recovery of xylene. From the MSDS, the percentage of xylenes in the sealer is 50 %. The evaporation rate of the sealer is 0.7. The specific gravity of the sealer is 1.0.

Using Equation (4), emissions of xylenes can be calculated as follows:

$$E_{\text{VOC}} = \sum_i [(A_i * SG_i) * (S_{\text{VOC},i}/100) * \text{Evap} * (1 - (\text{CE}/100))]$$
$$E_{\text{xylene}} = (50\,000\text{L}/\text{yr} * 1\text{ kg/L}) * (50/100) * 0.7 * (1 - (60/100))$$
$$= 7\,000\text{ kg xylenes}/\text{yr}$$

3.4 Emission Factors

An emission factor is a tool that is used to estimate emissions to the environment. In this Manual, it relates the quantity of substances emitted from a source, to some common activity associated with those emissions. Emission factors are obtained from US, European, and Australian sources and are usually expressed as the weight of a substance emitted, divided by the unit weight, volume, distance, or duration of the activity emitting the substance (eg. kilograms of sulfur dioxide emitted per tonne of aggregate handled).

Emission factors are used to estimate a facility's emissions by the general equation:

$$E_{\text{kpy},i} = [A * \text{OpHrs}] EF_i * [1 - (\text{CE}_i/100)] \quad (5)$$

where :

$$E_{\text{kpy},i} = \text{emission rate of pollutant } i, \text{ kg/yr}$$
$$A = \text{activity rate, t/hr}$$
$$\text{OpHrs} = \text{operating hours, hr/yr}$$
$$EF_i = \text{uncontrolled emission factor of pollutant } i, \text{ kg/t}$$
$$\text{CE}_i = \text{overall control efficiency of pollutant } i, \%$$

Emission factors developed from measurements for a specific hopper, aggregate loader, or other process may sometimes be used to estimate emissions at other sites. For example, a concrete batcher may have several units of similar model and size, so that if emissions were measured from one hopper or mixer, an emission factor could be developed and applied to similar hoppers or mixers at other sites. It is advisable to have the emission factor reviewed and approved by State or Territory environment agencies prior to its use for NPI estimations.

Example 4. - Calculating PM₁₀ Emissions

Table 6 shows that 0.05kg of PM₁₀ are emitted for each tonne of truck-mix concrete produced from all process sources. The emission factor is from a plant with no emission abatement or control technologies in place. The concrete plant operates for 1 500 hours per year.

$$\begin{aligned}
 EF_{PM_{10}} &= 0.05 \text{ kg/t} \\
 \text{Concrete production rate} &= 50 \text{ t/hr} \\
 \\
 PM_{10} \text{ emissions} &= EF_{PM_{10}} * \text{production rate} * \text{OpHrs} \\
 &= 0.05 \text{ kg/t} * 50 \text{ t/hr} * 1\,500 \text{ hr/yr} \\
 &= 2.5 \text{ kg/hr} * 1\,500 \text{ hr/yr} \\
 &= 3\,750 \text{ kg PM}_{10} / \text{yr}
 \end{aligned}$$

3.4.1 Industry-Wide Emission Factors

Table 6. Particulate Matter (PM₁₀) Emission Factors for Concrete Batching

Process	Uncontrolled Particulate Emission Factor ¹ (kg/tonne)	Emission Factor Rating Code
Sand and aggregate transfer to elevated bin	0.014	E
Cement unloading to elevated storage silo		
Pneumatic	0.13	D
Bucket elevator	0.12	E
Weigh hopper loading	0.01	E
Mixer loading (central mix)	0.02	E
Truck loading (truck mix)	0.01	E
Vehicle traffic (unpaved roads)	4.0 (kg/VKT) ^a	C
Wind erosion from sand and aggregate storage piles*	3.9 (kg/ha/day)	D
Total process emissions (truck mix)	0.05	E

Units are kg of PM₁₀ emitted per tonne of material handled.

Emissions are uncontrolled unless otherwise specified.

¹ USEPA Document AP-42 (1995).

^a VKT= Vehicle kilometres travelled.

* It should not be assumed that wind erosion emission factors are the same for concrete batching as they are for coal mining. The emission factors provided in this handbook for wind erosion refer specifically to overall PM emissions from concrete batching plants. Aggregate used by concrete batching plants is very different from coal mining particulates. The wind erosion emission factors in the mining handbook relate largely to studies undertaken at Hunter Valley coal mines in 1988. The relevance of this data to concrete batching plants, or indeed any other mining activity, requires clarification.

Speciating PM₁₀ Emissions

PM₁₀ emissions containing listed metals may require speciation into individual metal species where reporting thresholds for the metal have been triggered. Speciated PM₁₀ emissions are calculated using Equation (6).

$$E_{kpy,i} = Q_{PM10} * (EW_i / MW_{PM10}) \quad (6)$$

where:

$$\begin{aligned} E_{kpy,i} &= \text{total emissions of PM}_{10} \text{ species } i, \text{ kg/yr} \\ Q_{PM10} &= \text{amount of PM}_{10} \text{ emitted by the facility, kg/yr} \\ EW_i &= \text{elemental weight of substance } i, \text{ kg/kg-mole} \\ MW_{PM10} &= \text{molecular weight of PM}_{10}, \text{ kg/kg-mole} \end{aligned}$$

* Q_{PM10} in Equation (6) = $E_{kpy,i}$ in Equation (5)

The application of Equation (6) is illustrated in the following example.

Example 5. - Speciating PM₁₀ Emissions

This example demonstrates how speciated PM₁₀ emissions from total concrete batching processes at a facility may be calculated using the quantity of PM₁₀ emissions calculated from Example 4 and Equation (6):

$$\begin{aligned} Q_{PM10} &= 3750 \text{ kg ZnO per year emitted as PM}_{10} \\ C_i &= 80\% \text{ Zn in ZnO} \\ E_{kpy,Zn} &= Q_{PM10} * C_i / 100 \\ &= 3750 * 80 / 100 \\ &= 3000 \text{ kg Zn per year} \end{aligned}$$

3.4.2 Emission Factor Tables for Concrete Batching Activities

Table 7 illustrates Emission Factors for PM₁₀ for Concrete Batching Activities (kg/tonne material unless otherwise specified).

Table 7. Emission Factors for PM₁₀ for Concrete Batching Activities

Component/Activities	PM ₁₀ Emission Factors (kg/tonne)
1. Materials Handling	
a) unenclosed	
Default formula for PM ₁₀	$E_{PM10} = 0.75 * 0.001184 * [(U/2.2)^{1.3} / (M/2)^{1.4}]$
	NB For materials where M = 0, use default of 0.0036 kg/t handled
<u>Reduction Factors (RF)</u>	
- wind breaks	0.7
- water sprays	0.5
- chemical suppression	0.2
- enclosure (2 or 3 walls)	0.1
- covered stockpiles	0.0
b) bag filters venting outside	$E_{PM10} = 12\text{mg}/\text{m}^3 * \text{m}^3/\text{hr (flow)} * \text{hr}/\text{yr}$ $(\text{OpHrs}) * 10^{-6}$ $(12\text{mg}/\text{m}^3 = 80\% * \text{undiff. (15mg}/\text{m}^3))$
c) enclosed	0.0
2. Materials Storage - wind erosion from active stockpiles (kg/ha/hr-area of base)	
Default	0.3
<u>Reduction Factors (RF)</u>	
- wind breaks	0.7
- water sprays	0.5
- chemical suppression	0.2
- enclosure (2 or 3 walls)	0.1
- covered stockpiles	0.0
3. Equipment Traffic - greater than 5 tonnes gross (kg/VKT on unsealed roads)	
<u>Option 1</u>	$0.0019 * (\# \text{ wheels})^{3.4} * (\text{road surface material silt content (g}/\text{m}^2 \text{ as per AS3638)})^{0.2}$ 1.5 (75% of undiff. (2.0))
<u>Option 2 Default</u>	
<u>Reduction Factors (RF)</u>	
- watering (to eliminate visible dust)	0.25
- chemical spraying (rate)	0.2
4. Fuel Preparation & Drying - coal firing with dust collector	
	As per Section 1 b) bag filters
5. Limestone/Raw Material Crushing - material through crusher (kg/tonne)	
- uncontrolled	0.017
- fabric filter	0.0002
- wet or chemical suppression	0.0005
- wet scrubber	0.004

Table 7 Emission Factors for PM₁₀ for Concrete Batching Activities (cont')

Component/Activities	PM ₁₀ Emission Factors (kg/tonne)
6. Kiln	
a) <i>wet process</i>	
- electrostatic precipitator	0.3
b) <i>preheater kiln</i>	
- fabric filter	0.1
- electrostatic precipitator	0.1
c) <i>precalciner process kiln</i>	
- fabric filter	0.1
- electrostatic precipitator	0.1
7. Clinker Processing	
- fabric filter	0.001
- electrostatic precipitator	0.01
- gravel bed filter	0.03
8. Finished Cement Grinding	
- uncontrolled	0.3
- fabric filter	0.003
- electrostatic precipitator	0.004
(Assumes a default factor of 60mg/m ³ split into 40mg/m ³ PM ₁₀ and 20mg/m ³ > PM ₁₀)	

Source: The Cement Industry Federation Limited, 1998.

3.4.3 Predictive Emission Monitoring (PEM)

Predictive emission monitoring is based on developing a correlation between pollutant emission rates and process parameters. A PEM allows facilities to develop site-specific emission factors, or emission factors more relevant to their particular process.

Based on test data, a mathematical correlation can be developed which predicts emissions using various parameters.

4.0 Emission Estimation Techniques: Acceptable Reliability and Uncertainty

This section is intended to give a general overview of some of the inaccuracies associated with each of the techniques. Although the NPI does not mandate one emission estimation technique over another, this section does attempt to evaluate the available emission estimation techniques with respect to accuracy.

Several techniques are available for calculating emissions from concrete batching and concrete product manufacturing facilities. The technique chosen is dependent upon available data, available resources, and the degree of accuracy sought by the facility in undertaking the estimate. In general, site-specific data that are representative of normal operations are more accurate over industry-averaged data, such as the emission factors presented in Section 3.4.1. of this Manual.

4.1 Direct Measurement

Use of stack and/or workplace health and safety sampling data is likely to be a relatively accurate method of estimating air emissions from concrete batching and concrete product manufacturing facilities. However, collection and analysis of samples from facilities can be very expensive and especially complicated where a variety of NPI-listed substances are emitted and where most of these emissions are fugitive in nature. Sampling data from one specific process may not be representative of the entire manufacturing operation and may provide only one example of the facility's emissions.

To be representative, sampling data used for NPI reporting purposes would need to be collected over a period of time covering all aspects of production of concrete products.

In the case of CEMS, instrument calibration drift can be problematic and uncaptured data can create long-term incomplete data sets. However, it may be misleading to assert that a snapshot (stack sampling) can better predict long-term emission characteristics. It is the responsibility of the facility operator to properly calibrate and maintain monitoring equipment and the corresponding emissions data.

4.2 Mass Balance

Calculating emissions from a concrete product manufacturing facility using mass balance appears on the surface to be a straightforward approach to emissions estimations. However, few Australian concrete product manufacturing facilities consistently track material usage and waste generation with the overall accuracy needed for application of this method. Inaccuracies associated with individual material tracking or other activities inherent in each material handling stage often accumulate into large deviations of total facility emissions. Because emissions from specific materials are typically below 2 percent of gross consumption, an error of only ± 5 percent in any one step of the operation can significantly skew emissions estimations.

4.3 Engineering Calculations

Theoretical and complex equations or *models* can be used for estimating emissions from concrete product manufacturing, however, their use is a more complex and

time-consuming process than the use of emission factors. Emission equations require more detailed inputs than the use of emission factors but they do provide an emission estimate that is based on facility-specific conditions.

4.4 Emission Factors

Every emission factor has an associated emission factor rating (EFR) code. This rating system is common to EETs for all industries and sectors and therefore, to all Industry Handbooks. They are based on rating systems developed by the United States Environmental Protection Agency (USEPA), and by the European Environment Agency (EEA). Consequently, the ratings may not be directly relevant to Australian industry. Sources for all emission factors cited can be found in Section 5.0 of this document. The emission factor ratings will not form part of the public NPI database.

When using emission factors, you should be aware of the associated EFR code and what that rating implies. An A or B rating indicates a greater degree of certainty than a D or E rating. The less certainty, the more likely that a given emission factor for a specific source or category is not representative of the source type. These ratings notwithstanding, the main criterion affecting the uncertainty of an emission factor remains the degree of similarity between the equipment/process selected in applying the factor, and the target equipment/process from which the factor was derived.

The EFR system is as follows :

A	-	Excellent
B	-	Above Average
C	-	Average
D	-	Below Average
E	-	Poor
U	-	Unrated

In addition to the EFR code, the accuracy of emission factors is thoroughly dependent upon the degree of similarity between the reference source and the emission source being estimated.

5.0 References

USEPA. January 1995. *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, fifth edition, AP-42. Section 11, Mineral Products Industry, United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.*

USEPA. September 1995. *EPA Office of Compliance Sector Notebook Project. Profile of the Stone, Clay, Glass, and Concrete Products Industry.. United States Environmental Protection Agency, Office of Enforcement and Compliance Assurance. Washington, DC, USA.*

Written Communication from The Cement Industry Federation Limited, St Leonards, NSW, to the Queensland Environmental Protection Agency, Brisbane, QLD, August 1998.